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A. Annotated References on Monitoring

In addition to the monitoring references listed above, many documents contain information useful in designing a monitoring program for CSO controls. This section briefly highlights information from these documents, as well as from some of the documents listed above.

- The Water Environment Federation's *Combined Sewer Overflow Pollution Abatement Manual of Practice* No. FD-17 (WPCF, 1989) includes discussions on establishing planning objectives for characterizing receiving waters, their aquatic life, and meteorologic conditions; identifying critical events; evaluating system load characteristics; selecting analytic methods; mapping the system; developing the sampling plan; selecting field sampling procedures; monitoring CSS and environmental flow; and modeling.

- *Design of Water-Quality Monitoring Systems* (Ward et al., 1990) includes insightful discussions on the design of monitoring plans, the essential role of statistics, frameworks for designing water-quality information systems, quantification of information, data analysis, and the documentation of monitoring plans. This reference also includes four case studies of large-scale and long-term monitoring programs.

- *NPDES Storm Water Sampling Guidance Document*, EPA 833-B-92-001, (EPA, 1992) details EPA's requirements for monitoring storm water discharges. When such monitoring is required as a condition of a CSS's NPDES permit, monitoring efforts for CSO control should be coordinated with this required monitoring effort in order to maximize data collection efficiencies and minimize monitoring costs.

- *A Statistical Method for Assessment of Urban Stormwater Loads, Impacts, and Controls*, EPA 440/3-79-023, (Driscoll et al., 1979) discusses approaches for defining the purpose of monitoring programs; monitoring rainfall; using rainfall data to project and evaluate impacts; selecting monitoring sites; characterizing drainage basins; determining study periods, sampling frequencies, and sampling intervals during storms; selecting sampling procedures and sampling parameters; understanding special considerations for monitoring receiving waters; and using continuous monitoring. It also provides an extensive literature compilation regarding storm water and CSO monitoring.

- *Data Collection and Instrumentation in Urban Stormwater Hydrology* (Jennings, 1982) reviews data and instrumentation needs for urban storm water hydrology. This reference considers monitoring strategy design and the collection and use of data to characterize rainfall, other meteorological characteristics, streamflows, receiving water biologies and chemistries, and land use.

- *Use of Field Data in Urban Drainage Planning* (Geiger, 1986) describes rainfall-runoff processes and data collection constraints, the need to match data collection to study objectives, the use of data in urban drainage planning, the application and verification of models used in urban drainage planning, the validity of the design storm concept, the reliability of storm water simulations, and the real-time use of monitoring data in control and sewer system operation.

- "Water Body Survey and Assessment Guidance For Conducting Use Attainability Analyses (UAA)." In *Water Quality Standards Handbook* (EPA, 1994). The UAA concepts discussed in this Handbook include useful field sampling methods, modeling, and interpretation approaches in three Technical Support Documents for flowing waters, estuaries, and lakes (EPA, 1983b, 1984a, and 1984b).

- Several guidance documents that discuss or pertain to EPA's Waste Load Allocation (WLA) process also provide useful information on a wide range of topics that are potentially valuable when planning monitoring programs for CSO control:

  - *Guidance for State Water Monitoring and Waste Load Allocation Programs* (EPA, 1985) includes a chapter on monitoring for water-quality-based controls. It discusses the process of collecting and analyzing effluent and ambient monitoring data in establishing water quality standards and EPA's responsibilities in this process.

  - *Handbook - Stream Sampling for Waste Load Allocation Applications* (Mills et al., 1986) addresses sampling considerations for acquiring data on stream geometry, hydrology, meteorology, water quality, and plug flows. It also reviews sampling considerations for gathering data to meet various modeling needs.

  - "Nutrient/Eutrophication Impacts," Chapter 2 of *Technical Guidance Manual for Performing Waste Load Allocations, Book IV: Lakes and Impoundments,* (Mancini et al., 1983) primarily emphasizes modeling considerations. However, this chapter also provides useful introductions to approaches for estimating loading rates to standing water systems and needs for monitoring data to support modeling efforts.

  - *Technical Guidance Manual for Performing Waste Load Allocations, Book III: Estuaries, Part 2: Application of Estuarine Waste Load Allocation Models* (Martin et al., 1990) includes a chapter on monitoring protocols for calibrating and validating estuarine WLA models. It reviews the types of data needed, frequency of collection, spatial coverage, and quality assurance.

  - *Water Quality Assessment: A Screening Procedure for Toxic and Conventional Pollutants in Surface and Ground Water* (Mills et al., 1985a, b) presents a broad array of modeling and data management approaches for assessing aquatic fates of toxic organic substances, waste-load calculations, rivers and streams, impoundments, estuaries, and ground waters.

APPENDIX A

Table A-l
Checklist of Considerations for Documenting Monitoring Program Designs and Implementation (expanded from Ward et al., 1990)

Sample and Field Data Collection

Pre-Sampling Preparations

— Selecting personnel and identifying responsibilities
— Training personnel in safety and confined space entry; verifying first aid and wet-weather training, CPR, currency of vaccinations etc.)
— Preparing site access and obtaining legal consents
— Acquiring necessary scientific sampling or collecting permits
— Developing formats for field sampling logs and diaries
— Training personnel in pre-sampling procedures (e.g., purging sample lines, instrument calibration)
— Checking equipment availability, acquisition, and maintenance
— Scheduling sample collection (random? regular? same-time-of-day?)
— Preparing pre-sampling checklist

Sampling Procedures

— Procedures documentation
— Staff qualifications and training
— Sampling protocols
— Quality-control procedures (equipment checks, replicates, splits, etc.)
— Required sample containers
— Sample numbers and labeling
— Sample preservation (e.g, "on ice" or chemical preservative)
— Sample transport (delivery to laboratory)
— Sample storage requirements
— Sample tracking and chain-of-custody procedures
— Quality control or quality assurance
— Field measurements
— Field log and diary entries
— Sample custody and audit records

Post-Sampling Follow Up

— Filing sample logs and diaries
— Cleaning and maintaining equipment
— Disposing of chemical wastes properly
— Reviewing documentation and audit reports

Table A-l (continued)
Checklist of Considerations for Documenting Monitoring Program Designs and Implementation (expanded from Ward et al., 1990)

Laboratory Analysis

Preparations Prior to Sample Analysis

__ Verifying use of proper analytical methods
__ Scheduling analyses
__ Verifying sample number
__ Defining a recording system for sample results
__ Applying a system to track each sample through the lab
__ Maintaining and calibrating equipment
__ Preparing quality control solutions

Sample Analysis

__ Sample analysis methods and protocols
__ Use of reference samples, duplicates, blanks, etc.
__ Quality control and quality assurance compliance
__ Sample archiving
__ Proper disposal of chemical wastes
__ Full documentation in bench sheets

Data Record Verification

__ Coding sheets, data loggers
__ Data verification procedures and compliance with project plan
__ Verifying analysis of splits within data quality objectives
__ Assigning data-quality indicators and explanations

Data Management

__ Selecting appropriate hardware and software
__ Documenting data entry practices and data validation (e.g., entry-range limits, duplicate entry checking)
__ Data tracking
__ Developing data-exchange protocols
__ Formatting data for general availability

Data Analysis

__ Selecting software
__ Handling missing data and non-detects
__ Identifying and using data outliers
__ Planning graphical procedures (e.g., scatter plots, notched-box and whisker)
__ Parametric statistical procedures
__ Non-parametric statistical procedures
__ Trend analysis procedures
__ Multivariate procedures
__ Quality control checks on statistical analyses

Table A-l (continued)
Checklist of Considerations for Documenting Monitoring Program Designs and Implementation (expanded from Ward et al., 1990)

Reporting

- ___ Scheduling reports - timing, frequency, and lag times following sampling
- ___ Designing report contents and formats
- ___ Designing planned tables and graphics
- ___ Assigning report sign-off responsibility(ies)
- ___ Determining report distribution recipients and availability
- ___ Planning use of paper and electronic formats
- ___ Presentations

Information Use

- ___ Identifying and applying decision or trigger values, resulting action
- ___ Implementing construction, control, and/or monitoring design alternatives
- ___ Planning public-release procedures

General

- ___ Contingencies
- ___ Follow-up procedures
- ___ Data management
- ___ Data analysis
- ___ Reporting
- ___ Information use

Table A-2
Checklist for Reviewing CSO Monitoring Plans

CSO Drainage and Sewer System Map

- ___ Up-to-date
- ___ Shows "as-built" sewer system
- ___ Shows drainage areas with land use information
- ___ Shows location of major industrial sewer users
- ___ Shows location of all direct discharge points, including all related CSO, POTW, storm water, and industrial discharges
- ___ Distinguishes bypass points from CSOs points and shows locations
- ___ Shows locations of CSO quantity and quality monitoring sites
- ___ Identifies receiving waters
- ___ Identifies designated and existing uses of receiving waters
- ___ Shows areas of historical use impairment

CSO Volume

- ___ Identifies number of storms to be monitored
- ___ Identifies number of CSO outfalls to be monitored
- ___ Ensures that sampling points include major CSOs
- ___ Provides for monitoring of POTW influent flow
- ___ Ensures adequacy of method of flow measurement
- ___ Identifies frequency of flow measurement during each storm event
- ___ Identifies storm statistics to be reported-mean, maximum, duration
- ___ Identifies storm statistics to be reported for all storms during the study period

CSO Quality

- ___ Identifies number of storms to be monitored
- ___ Identifies number of CSO outfalls to be monitored
- ___ Ensures that sampling points include major CSOs
- ___ Provides for monitoring of POTW influent quality
- ___ Provides for monitoring of drainage areas representative of land use and sewer users
- ___ Identifies method and frequency of sampling
- ___ Identities parameters to be analyzed
- ___ Ensures adequacy of detection limits
- ___ Identifies toxicity test(s) to be conducted
- ___ Identifies receiving water(s) to be sampled
- ___ Provides for monitoring of aesthetics

APPENDIX B

Table B-l

Documents and Screening Manual (Mills et al.) for Analysis of Conventional Pollutants

Data Requirements	Streeter-Phelps DO Analyses-[a]	NH3 Toxicity Calculations-[b]	Algal Predictions Without Nutrient Limitations-[c]	Algal Predictions With Nutrient Limitations-[c]	Algal Effects on Daily Average DO-[c]	Algal Effects on Diurnal DO-[c]
Hydraulic and Geometric Data						
Flow Rates-[d]	x	x	x	x	x	x
Velocity	x	x	x	x	x	x
Depth	x	x	x	x	x	x
Cross-sectional area	x	x	x	x	x	x
Reach length	x	x	x	x	x	x
Constituent Concentrations-[e]						
DO	x					
CBOD, NBOD	x					
NH3		x				
Temperature	x	x	x	x	x	x
Inorganic P			x	x	x	x
Inorganic NPDES			x	x	x	x
Chlorophyll a [f]			x	x	x	x
pH		x				
DO/BOD Parameters						
Restoration rate coefficient	x				x	x
Sediment Oxygen Demand	x					
CBOD decay rate	x					
CBOD removal rate	x					
NBOD decay rate	x					
NH3 oxidation rate					x	x
Oxygen per unit chlorophyll a						
Algal oxygen production rate	x					
Algal oxygen respiration rate	×					

Table B-l (continued)
Data Requirements for Hand-Calculation Techniques Described in WLA Guidance Documents and Screening Manual (Mills et al.) for Analysis of Conventional Pollutants

Data Requirements	Streeter-Phelps DO Analyses-[a]	NH3 Toxicity Calculations-[b]	Algal Predictions Without Nutrient Limitations-[c]	Algal Predictions With Nutrient Limitations-[c]	Algal Effects on Daily Average DO-[c]	Algal Effects on Diurnal DO-[c]
Phytoplankton Parameters						
Maximum growth rate			x	x	x	x
Respiration rate			x	x	x	x
Settling velocity			x	x	x	x
Saturated light intensity			x	x	x	x
Phosphorous half-saturation constant				x	x	x
Nitrogen half-saturation				x	x	x
Phosphorous to chlorophyll ratio			x	x	x	x
			x	x	x	x
ratio						

Data Requirements	Streeter-Phelps DO Analyses-[a]	NH3 Toxicity Calculations-[b]	Algal Predictions Without Nutrient Limitations-[c]	Algal Predictions With Nutrient Limitations-[c]	Algal Effects on Daily Average DO-[c]	Algal Effects on Diurnal DO-[c]
Light Parameters						
Daily solar radiation			x	x	x	x
			x	x	x	x
Light extinction coefficient			x	x	x	x

a) Streeter-Phelps DO calculations are described in Chapter 1 of Book II of the WLA guidance documents (Table 1- 1) and the Screening Manual (Mills et. al.).

b) Ammonia toxicity calculations are described in Chapter 1 of Book II of the WLA guidance documents.

c) Algal predictions and their effects on DO are discussed in Chapter 2 of Book II of the WLA guidance documents.

d) Flow rates are needed for the river and all point sources at various points to define nonpoint flow,

e) Constituent concentrations are needed at the upstream boundary and all point sources.

f) Chlorophyll a concentrations are also needed at the downstream end of the reach to estimate net growth rates,

Table B-2
Model Input Parameters for Qual-2E

Input Parameter	Variable by Reach	Input Parameter	Variable by Reach	Variable with Time
Dissolved Oxygen Parameters		*Nonconservative Constituent Parameters*		
Reservation rate coefficients	Yes	Decay rate		
O_2 consumption per unit of NH_3 oxidation				
O_2 consumption per unit of NO_2 oxidation		*Meteorological Data*		
O_2 production per unit photosynthesis		Solar radiation		Yes
O_2 consumption per unit respiration		Cloud cover		Yes
Sediment oxygen demand	Yes	Dry bulb temperature		Yes
		Wet bulb temperature		Yes
Carbonaceous BOD Parameters		Wind speed		Yes
CBOD decay rate	Yes	Barometric pressure		Yes
CBOD settling rate	Yes	Elevation		
		Dust attenuation coefficient		
Organic Nitrogen		Evaporation coefficient		
Hydrolize to ammonia	Yes			
		Stream Geometry Data		
Ammonia Parameters		Cross-sectional area vs. depth	Yes	
Ammonia oxidation rate	Yes	Reach length	Yes	
Benthic source rate	Yes			
		Hydraulic Data (Stage-flow Curve Option)		
Nitrite Parameters		Coefficient for stage-flow equation	Yes	
Nitrite oxidation rate	Yes	Exponent for stage-flow equation	Yes	
		Coefficient for velocity-flow equation	Yes	
Nitrate Parameters		Exponent for velocity-flow equation	Yes	
None				
		Hydraulic Data (Manning's Equation Option)		
Organic Phosphorous		Manning's n	Yes	
Transformed to diss. p	Yes	Bottom width of channel	Yes	
		Side slopes of channel	Yes	
Phosphate Parameters		Channel slope	Yes	
Benthic source rate	Yes			

Table B-2 (continued)
Model Input Parameters for Qual-2E

Input Parameter	Variable by Reach	Input Parameter	Variable by Reach	Variable with Time
Phytoplankton Parameters		*Flow Data*		
Maximum growth rate		Upstream boundaries	Yes	
Respiration rate		Tributary inflows	Yes	
Settling rate	Yes	Point sources	Yes	
Nitrogen half-saturation constant		Nonpoint sources	Yes	
Phosphorous half-saturation constant		Diversions	Yes	
Light half-saturation constant				
Light extinction coefficient	Yes	*Constituent Concentrations*		
Ratio of chlorophyll a to algal biomass	Yes	Initial conditions	Yes	
Nitrogen fraction of algal biomass		Upstream boundaries		Yes
Phosphorous fraction of algal biomass		Tributary inflows	Yes	
		Point sources	Yes	
Coliform Parameters		Nonpoint sources	Yes	
Die-off rate	Yes			

Table B-3
Comparison of Qual-II With Other Conventional Pollutant Models Used in Waste Load Allocations

Model	Temporal Variability: Water Quality	Temporal Variability: Hydraulics	Variable Loading Rated	Types of Loads	Spatial Dimensions	Water Body	Water Quality Parameters Modeled	Process Simulated: Chemical/Biological	Process Simulated: Physical
DOSAG-I	Steady-state	Steady-state	No	multiple point source	I-D	stream network	DO, CBOD, NBOD, conservative	1st-order decay of NBOD, CBOD, coupled DO	dilution, advection, reservation
SNSIM	Steady-state	Steady-state	No	multiple point sources & nonpoint sources	I-D	stream network	DO, CBOD, NBOD, conservative	1st-order decay of NBOD, CBOD, coupled DO, benthic demand (s), photosynthesis (s)	dilution, advection, reservation
QUAL-II	Steady-state or dynamic	Steady-state	No	multiple point sources & nonpoint sources	I-D	stream network	DO, CBOD, temperature, ammonia, nitrate, nitrite, algae, phosphate, coliforms, non-conservative substances, three conservative substances	1st-order decay of NBOD, CBOD, coupled DO, benthic demand (s), CBOD settling (s), nutrient-algal cycle	dilution advection, reservation, heat balance
RECEIV-II	Dynamic	Dynamic	Yes	multiple point sources	1-D or 2-D	stream network or well-mixed estuary	DO, CBOD, ammonia, nitrate, nitrite, total nitrogen, phosphate, coliforms, algae, salinity, one metal ion	1st-order decay of NBOD, CBOD, coupled DO, benthic demand (s), CBOD settling (s), nutrient-algal cycle	dilution, advection, reservation

(s) = specified.

Table B-4
Methods for Determining Coefficient Values in Dissolved Oxygen and Eutrophication Models

Model Parameter	Symbol	Method Determination
Dissolved Oxygen Parameters		
Reaeration rate coefficient	K_{Ss}	Compute as a function of depth and velocity using an appropriate formula, or measure in field using tracer techniques.
O_2 consumption per unit of NH3 oxidation	a1	Constant fixed by biochemical stoichiometry
O_2 consumption per unit NO2 oxidation	a2	Constant fixed by biochemical stoichiometry
O_2 production per unit photosynthesis	a3	Literature values, model calibration and measurement by light to dark bottles and chambers.
O_2consumption per unit respiration	a4	Literature values and model calibration.
Sediment oxygen demand	K_{SOD}	In situ measurement and model calibration.
Carbonaceous BOD Parameters		
CBOD decay rate	K_d	Plot CBOD measurements on semi-log paper or measure in laboratory.
CBOD settling rate	K_s	Plot CBOD measurements on semi-log paper and estimate from steep part of curve.
Ammonia Parameters		
Ammonia oxidation rate	K_{N1}	Plot TKN measurements and NO_3+NO_2 measurements on semi-log paper.
Benthic source rate	K_{BEN}	Model calibration.
Nitrite Parameters		
Nitrite oxidation rate	K_{N2}	Use literature values and calibration, since this rate is much faster than the ammonia oxidation rate.
Phosphate Parameters		
Benthic source rate	K_{BEP}	Model calibration.

Table B-4 (continued)
Methods for Determining Coefficient Values in Dissolved Oxygen and Eutrophication Models

Model Parameter	Symbol	Method Determination
Phytoplankton Parameters		
Growth rate	μ	Literature values and model calibration, or measure in field using light-dark bottle techniques.
Respiration rate	r	Literature values and model calibration, or measure in field using light-dark bottle techniques.
Settling rate	V_s	Literature and model calibration.
Nitrogen fraction of algal biomass	a5, a6, a7	Literature values and model calibration or laboratory determinations from field samples.
Phosphorous fraction of algal biomass	a8, a9	Literature values and model calibration or laboratory determinations from field samples.
Half-saturation constants for nutrients	K_n, K_p	Literature values and model calibration.
Saturating light intensity or half-saturation constant for light	I_s or K_L	Literature values and model calibration.

Table B-5
Summary of Data Requirements for Screening Approach for Metals in Rivers

Data	Calculation Methodology	Remarks
Hydraulic Data		
1. Rivers:		
• River flow rate, Q	D, R, S, L	An accurate estimation of flow rate is very important because of dilution considerations. Measure or obtain from USGS gage.
• Cross-sectional area, A	D, R, S	
• Water depth, h	D, R, S, L	Average water depth is cross-sectional area divided by surface width.
• Reach lengths, x	R, S	
• Stream velocity, U	R, S	Required velocity is distance divided by travel time. It can be approximated by Q/A only when A is representative of the reach being studied.
2. Lakes:		
• Hydraulic residence time, T	L	Hydraulic residence times of lakes can vary seasonally as the flow rates through the lakes change.
• Mean depth, H	L	Lake residence times and depths are used to predict settling of absorbed metals in lakes.
Source data		
1. Background		
• Metal concentrations, C_t	D, R, S, L	Background concentrations should generally not be set to zero without justification.
• Boundary flow rates, Q_u	D, R, S, L	
• Boundary suspended solids, Su	D, R, S, L	One important reason for determining suspended solids concentrations is to determine the dissolved concentration, C, of metals based on C_T, S, and K_p However, if C is known along with C_T and S, this information can be used to find K_p.
• Silt, clay fraction of suspended solids	L	
• Locations	D, R S, L	

Table B-5 (continued)
Summary of Data Requirements for Screening Approach for Metals in Rivers

2. Point sources		
• Locations	D, R, S, L	
• Flow rate, Q_w	D, R, S, L	
• Metal concentration, C_{tw}	D, R, S, L	
• Suspended solids, S_W	D, R, S, L	
Bed Data		
• Depth of contamination		For the screening analysis, the depth of contamination is most useful during a period of prolonged scour when metal is being input into the water column from the bed.
• Porosity of sediments, n		
• Density of solids in sediments (e.g., 2.7 for sand) u_s		
• Metal concentration in bed during prolonged scour period, C_{t2}		
Derived Parameters		
• Partition coefficient, K_p	All	Partition coefficient is a very important parameter. Site-specific determination is preferable.
• Settling velocity, w_s	S,L	Parameter derived based on suspended solids vs. distance profile.
• Resuspension velocity, W_{rs}	R	Parameter derived based on suspended solids vs. distance profile.
Equilibrium Modeling		
• Water quality characterization of river:	E	Equilibrium modeling is required only if predominant metal species and estimated solubility controls are needed.
• pH		
• Suspended solids		
• Conductivity		
• Temperature		
• Hardness		Water quality criteria for many metals are keyed to hardness, and allowable concentrations increase with increasing hardness.
• Total organic carbon		
• Other major cations and anions		

*D - Dilution (Includes total dissolved and adsorbed phase concentration predictions)

R - dilution and resuspension.

S - dilution and settling.

L - lake.